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The Results Are In: Deregulation's Impact on Nuclear Power's Performance

An unprecedented period of deregulation and consolidation in the U.S. nuclear power industry began in the late 1990s. Nearly half of the country's 103 nuclear reactors were sold to independent power producers. These divestitures have led to substantial market consolidation and today the three largest companies control more than one-third of all U.S. nuclear capacity. So how are these plants performing now? Did divestiture improve or diminish their operating performance?

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For four decades all nuclear power reactors in the U.S. were owned by regulated utilities. Few utilities owned more than one or two reactors and utilities were allowed to recover their operating expenses as well as earn a rate of return on all capital investments in generating equipment as long as that equipment was "used and useful." This created little incentive for companies to operate their plants efficiently, including their nuclear reactors, because they received this compensation regardless of the level of performance.

Recognizing that traditional cost-of-service regulation provided little incentive for cost-minimization, several states began to deregulate their electricity markets beginning in the late 1990s. Regulators also strongly encouraged utilities to sell all or part of their existing generating portfolios. The timing of the nuclear plant divestitures followed this broader industry trend.

In their study "Deregulation, Consolidation, and Efficiency: Evidence from U.S. Nuclear Power" (EI @ Haas WP-217), **Lucas Davis** and **Catherine Wolfram** (University of California, Berkeley) analyze the operating efficiency of the nuclear power plants before, during and after market restructuring. They use a unique, 40-year monthly panel of data for all nuclear reactors in the U.S. and find that deregulation and consolidation were associated with a 10 percent increase in operating efficiency. The efficiency gains were experienced broadly across reactors of different types, manufacturers, and vintages.

These results imply a substantial increase in electricity production. Davis and Wolfram estimate that the increase in electricity production due to deregulation and consolidation exceeded 40 billion kilowatt hours

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Do Consumers Accurately Predict Future Gasoline Prices?

Consumers' predictions about future energy prices influence their willingness to pay for investments in energy efficiency. When deciding whether to purchase a more fuel efficient car, the consumer is implicitly forecasting the future price of gasoline and deciding if it is worthwhile to forego a less fuel efficient car based on estimated gasoline savings.

The same calculation takes place when a consumer decides to purchase any energy-using durable good such as an air conditioner or large appliance and when a homeowner decides whether to install energy efficient windows or additional insulation. The benefit side of the purchase decision includes a forecast of the energy price saved and is part of the calculation to pursue the investment.

How do consumers form their beliefs about future energy prices? Are their beliefs reasonable? In a new paper "What Do Consumers Believe About Future Gasoline Prices?" (EI @ Haas WP-215), **Soren Anderson** (Michigan State University), **Ryan Kellogg** (University of Michigan), and **James Sallee** (University of Chicago) seek answers to these questions for the important case of gasoline. Using high-quality survey data that directly elicits consumer beliefs, Anderson, Kellogg and Sallee find that in normal economic conditions the average consumer expects the future real price of gasoline to equal the current price.

Addressing these questions is central to understanding markets for energy-using durable goods and, by extension, for designing policies to curtail greenhouse gas emissions and other energy-related externalities. A large and growing literature tests empirically whether consumers fully value energy efficiency when purchasing durable goods. These tests are important because if consumers undervalue energy efficiency – as this literature sometimes finds – then policies designed to raise the price of carbon-intensive fuels, such as a carbon tax or cap-and-trade program, may not alone be the best policy. In that case, efficiency standards or subsidies may be justified as complements to policies that increase fuel prices.

Research that attempts to estimate consumers' valuation of energy efficiency must explicitly model consumers' beliefs about future energy prices and may draw biased inferences if these beliefs are incorrect. Most studies of automobile demand assume that consumers adopt no-change forecasts for future gasoline prices in real terms, that is, they assume that the expected future price is the current price. If consumers' beliefs deviate significantly from this assumption, however, then researchers may under-estimate or over-estimate consumers' valuation of fuel economy, depending on the direction of the deviation. The main goal of Anderson, Kellogg, and Sallee's study is to test this no-change belief assumption directly.

The researchers conduct their analysis using data on consumer beliefs about future gasoline prices from the Michigan Survey of Consumers (MSC). Every month the MSC asks a nationally representative sample of about 500 respondents to report their beliefs about the current state of the economy and to forecast several economic variables. Since 1993, the MSC has regularly asked respondents to report whether they think gasoline prices will be higher or lower (or the same) in five year's time and then to forecast the exact price change. The survey was designed to elicit expectations about gasoline price changes in nominal terms. The survey also includes questions about consumers' general price inflation expectations, which, along with data on current gasoline prices from the U.S. Energy Information Administration and the Consumer Price Index from the Bureau of Labor Statistics, can be used to calculate consumer forecasts for the future gasoline price in real dollars. The study period is from January 1993 to December 2009. The researchers are the first to use this unique dataset.

Figure 1 presents the mean current price of gasoline, the mean forecast level and the mean forecast change over 5 years during the study period, all in real terms. Note that the real forecast hovers near zero for most of the study period, with large deviations only around September 11, 2001 and the large price swings during the financial crisis of 2008. Thus, this figure indicates that the average MSC respondent forecasts the real price of gasoline in 5 years to equal the price of gasoline at

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California's Building Standards: New Homes Use More Electricity

California's per capita total electricity sales have been flat since the mid 1970s when landmark legislation for energy efficiency was passed, while sales for the rest of the United States over this period have gone up by 50 percent. California's aggressive building code standards have often been credited with achieving much of these electricity savings. But are new buildings, new residential homes in particular, more energy efficient? How do they compare relative to houses built before the building codes were enacted?

In comparing total residential electricity use, there are many factors that can increase or decrease usage. **Howard Chong** (Cornell University) teases apart some of the different factors that affect electricity usage and provides new insights in his paper "Building Vintage and Electricity Use: Old Homes Use Less Electricity in Hot Weather" (EI @ Haas WP-211). Chong studies whether electricity use in newer or older residential buildings rises more in response to high temperature. Professor Chong looks at the temperature response of a house, which is defined as the percentage increase in electricity use due to a 1° Fahrenheit increase in outside temperature. Temperature response is a better measure of the performance of a house than total electricity use because it focuses the heating and cooling response of a house to a change in weather.

California has had the most extensive energy efficiency standards in the United States applied to new buildings. The question of whether newer or older residential buildings in California have higher temperature response has not been studied before using actual field data. Engineering models have predicted strong reductions in energy use (both peak and total use) due to these standards, all else held equal, but other factors can offset these decreases. Chong uses field data to estimate the temperature response across houses of different vintages.

Chong was able to develop a comprehensive dataset that includes all electricity billing data for each household, detailed county assessor's property information on each house, and census block group data, including median square footage and proportion of houses with central air conditioning. His paper focuses on Riverside County in California because it is an inland area with a wide range of temperatures and considerable variation in building vintage. (See Figure 1.) Table 1 shows the summary statistics for the data

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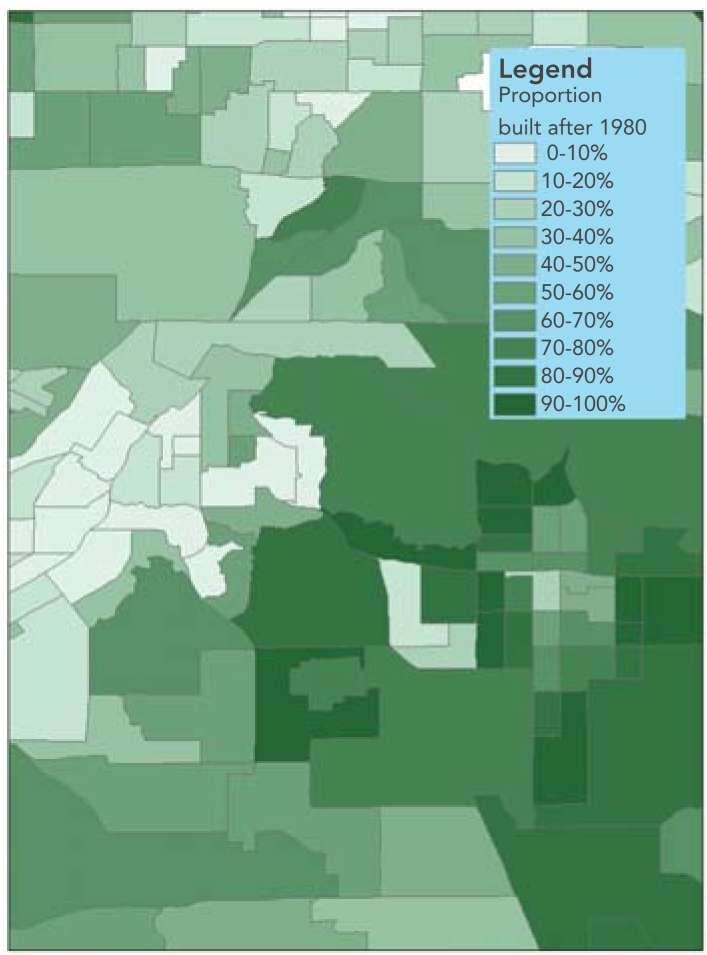
FIGURE 1: VARIATION IN BUILDING VINTAGE IN RIVERSIDE COUNTY, CALIFORNIA

SHADING REPRESENTS PROPORTION OF BUILDINGS BUILT SINCE 1980. DARKER MEANS HIGHER PROPORTION OF NEW BUILDINGS.



CALIFORNIA'S BUILDING STANDARDS: NEW HOMES USE MORE ELECTRICITY

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using the assessor's data. Most single homes (88%) have central air conditioning but air conditioning penetration varies substantially by the age of the house. The newest homes almost all have air conditioning, but less than half of the older homes have central air conditioning.

Chong's results show that new buildings (1970 -2000) have a higher temperature response, i.e., use more electricity, than old buildings (pre-1970). However, newer buildings are more likely to have central air conditioning and be larger. Chong analyzes the impacts of these characteristics separately and finds that central air conditioning strongly positively increases temperature response. Square footage negatively affects temperature response; this means that the percentage increase in electricity on a hot day is systematically less for larger buildings. Controlling for central air conditioning and square footage, temperature response is still larger for new buildings. This means that other factors have outweighed the energy-saving impacts of building standards.

There are multiple other factors that could be driving this greater temperature response in newer houses. Behavioral responses, such as those driven by a rebound effect can increase temperature response. This would mean that part of the increase is due to an increase in comfort from using more cooling services. New buildings may differ in their thermal design in that they may have taller ceilings, more structural complexity, or a higher window-to-wall ratio; all of which may increase the electricity needed to cool a building. It is also possible that people who favor more cooling services are more likely to live in new buildings. These are factors that would need to be carefully considered when designing and evaluating building standards. Unfortunately, the current data cannot separate out these factors, which warrant further study.

Regardless, Chong's result that the composition of the building stock is changing to something more temperature responsive have two main policy implications, one for load forecasting and one for the impacts of climate change. First, in conducting load forecasts, these results suggest that new construction will increase the average temperature response and increase peak load on the hottest days. Looking at the issue of air conditioning statewide, these results potentially could have an even greater effect. This is because coastal areas have historically had a lower amount of air conditioning, but a California Energy Commission study finds that there has been an unexpected increase in air conditioning saturation in cooler areas. Coastal areas that have very low ownership of air conditioners in older buildings have dramatically increased air conditioner ownership for newly built buildings.

Second, climate change impacts will be exacerbated by the increased temperature response from newer houses. By 2050, Riverside's population is predicted to more than double. Chong estimates that for a 5° Fahrenheit increase due to climate change, the temperature response will be about 2 -3 percent higher with the addition of new buildings compared to the current building stock. **EI@HASS**

Howard Chong, "Building Vintage and Electricity Use: Old Homes Use Less Electricity in Hot Weather," EI @ Haas WP-211, November 2010.

TABLE 1: SUMMARY STATISTICS

Variable	Mean	Std. Dev	Min	Max
BILLING DATA				
USE PER DAY	24.73	14.20	2.03	79.97
DAYS	30.43	1.50	26	34
ASSESSOR'S DATA				
BUIDING AGE				
Proportion built prior to 1970	0.15	0.36	0	1
Proportion built in 1970s	0.16	0.36	0	1
Proportion built in 1980s	0.54	0.5	0	1
Proportion built in 1990s	0.15	0.36	0	1
OTHER CHARACTERISTICS				
Square Feet	1750	480	360	7138
Has Central Air Conditioning?	0.88	0.28	0	1
for pre 1970s	0.407			
for 1970s	0.847			
for 1980s	0.986			
for 1900s	0.995			
OBSERVATIONS (no subsampling)	5,106,398			

THE RESULTS ARE IN: DEREGULATION'S IMPACT ON NUCLEAR POWER'S PERFORMANCE

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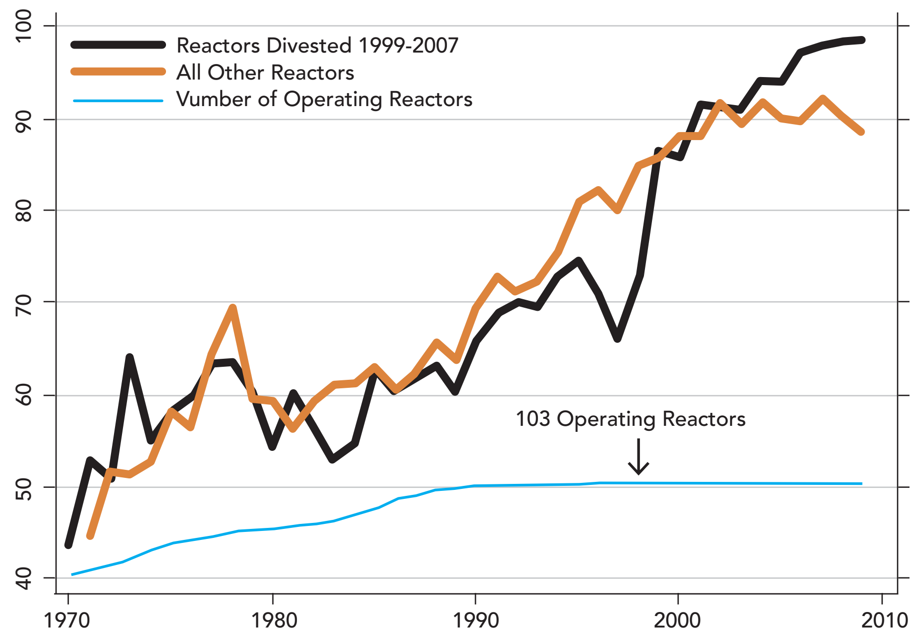
annually. At current average wholesale prices, the value of increased electricity production is approximately $2.5 billion annually. This increase is almost pure efficiency gain, achieved without building a single new plant or constructing a single additional mile of transmission capacity.

In addition, because the increased electricity production displaces mostly baseload coal-and natural gas-fired power, these gains in efficiency also have substantial implications for the environment, implying an annual decrease of 38 million metric tons of carbon dioxide emissions. To put this into perspective, this is more carbon abatement than was achieved by all the U.S. wind and solar generation combined during the same period. An important lesson to take away from this result is that even modest improvements in the operating efficiency of conventional technologies can have substantial environmental implications when that technology makes up a large share of the total market.

Figure 1 plots annual average operating efficiency for reactors that were divested and all other reactors. During the 1980s and 1990s the average efficiency for divested reactors tends to be somewhat lower than the average efficiency for all other reactors. Then beginning in the late 1990s with the first divestitures, the average efficiency for divested reactors increases sharply and continues to increase during the 2000s. For every year between 2003 and 2009 the average efficiency for divested reactors is higher than the average efficiency for all other reactors. This pattern is consistent with a causal relationship between deregulation and operating efficiency for a group of reactors that were perennial underachievers converted almost immediately into a group of reactors that consistently outperform the rest of the industry. The pronounced dip in efficiency during the late 1990s among reactors that were subsequently divested can be explained by several extended outages. During 1996, 1997, and 1998 ten reactors experienced 12+ month outages - seven of which were reactors that were subsequently divested. Davis and Wolfram address potential concerns about selection bias but find that the efficiency results are similar when they run their analysis excluding the reactors with the long outages.

FIGURE 1: NET GENERATION SCALED BY REACTOR DESIGN CAPACITY, 1970-2009



Davis and Wolfram perform additional analyses to understand the mechanisms driving the increase in efficiency. They explore three possible mechanisms that could lead to increased monthly generation at divested reactors. A reactor will generate more electricity if it 1) produces more when it is at maximum capacity, 2) is available more days, or 3) produces at a higher capacity factor when available. The results suggest that the increase in operating efficiency is primarily explained by the first two channels - an increase in maximum capacity and a decrease in outages.

U.S. nuclear power plants are licensed to operate at a particular maximum heat level. However, plant operators can petition to have this maximum thermal capacity increased. This is known as an "uprate." Since 1970 nuclear uprates have added 6,000 megawatts of total electric generating capacity.

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DO CONSUMERS ACCURATELY PREDICT FUTURE GASOLINE PRICES?

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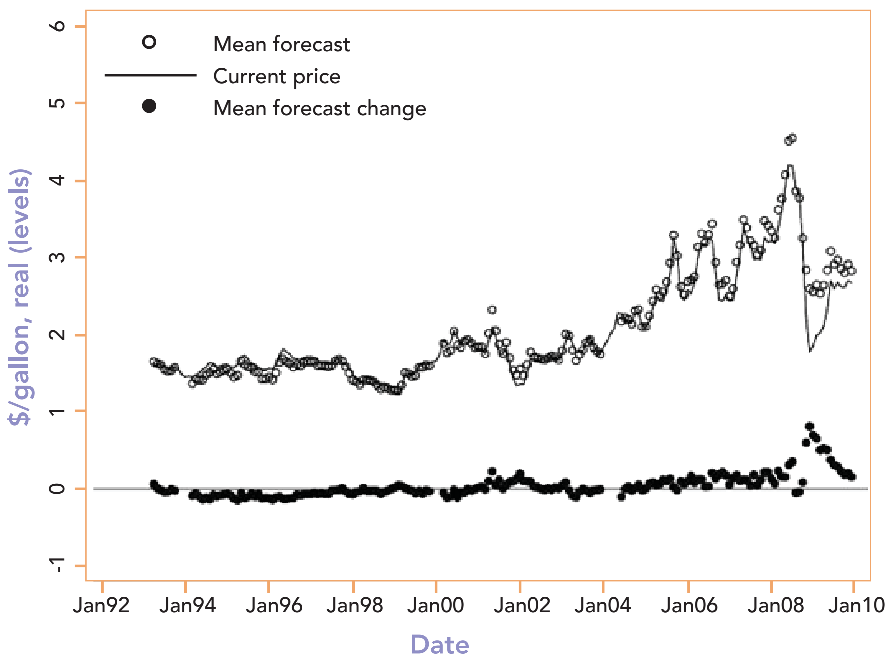
the time of the survey. That is, consumer forecasts appear to be consistent with a *real* no-change forecast model. Previous studies have shown that a no-change forecast has historically been a more accurate predictor of future crude oil prices than forecasts based, for example, on futures markets, expert opinion, or more sophisticated statistical models. Thus, one conclusion that can be drawn from the research described here is that consumers do in fact have reasonable beliefs about future gasoline prices.

FIGURE 1: REAL GASOLINE PRICES AND FORECASTS



The only large, sustained deviation from a real no-change forecast is during the financial crisis of 2008, during which the price of gasoline fell by half. Consumers at this time expected prices to rebound. This prediction turned out to be correct: prices had already risen by about one-third of the original decline within six months. Thus, in the sample, when consumer beliefs deviated substantially from a real no-change forecast, the deviation was accurate.

These results imply that applied researchers are likely justified in assuming that consumers, on average, employ a no-change forecast when modeling consumer demand for energy-using durables. A caveat to this finding is that the researchers found substantial variation among the respondents in the dataset so while the average respondent believes the future price of gasoline will equal the current price, there is a wide range of individual responses. In future work, the researchers will explore how variation in individual beliefs about future gasoline prices correlates with preferences for efficient versus inefficient cars and how these correlations vary over time. EI@HASS

Soren T. Anderson, Ryan Kellogg, and James M. Sallee, "What Do Consumers Believe About Future Gasoline Prices?," EI @ Haas WP-215, April 2011.

THE RESULTS ARE IN: DEREGULATION'S IMPACT ON NUCLEAR POWER'S PERFORMANCE

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In Figure 2 Davis and Wolfram show that since 2000 divested nuclear plants sharply increased their maximum thermal capacity relative to all other plants.

Each year nuclear outages peak twice, once during the spring and again in the fall. The most common explanation for a reactor outage is refueling. Figure 3 illustrates how the fraction of reactors not operating by day has changed over time. At the beginning of the sample the annual pattern for both divested and non-divested plants is reasonably similar but by the end of the sample outages are considerably less frequent among divested reactors. This holds for almost all days during the entire year, with particularly large differences during the late spring and late fall.

These results provide some of the clearest evidence to date of efficiency gains from the deregulation of electricity markets. As predicted by economic theory, removing regulation has provided incentives for firms to increase efficiency, reduce costly outages, and make prudent investments in capacity. As plants have been sold to private companies, the financial cost of poor operating efficiency has transferred from ratepayers to shareholders, and companies have responded by achieving the highest levels of nuclear reactor operating efficiency in history. EI@HASS

Lucas W. Davis and Catherine Wolfram, "Deregulation, Consolidation, and Efficiency: Evidence from U.S. Nuclear Power," EI @ Haas WP-217, August 2011.

FIGURE 2: LICENSED THERMAL CAPACITY AS A PERCENT OF ORIGINAL LICENSE, 1970-2009

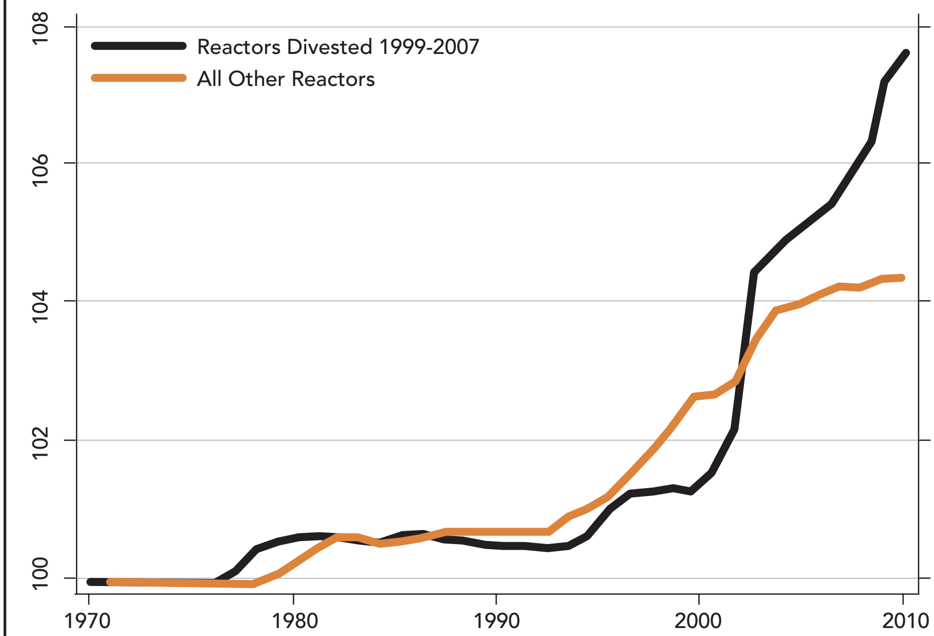
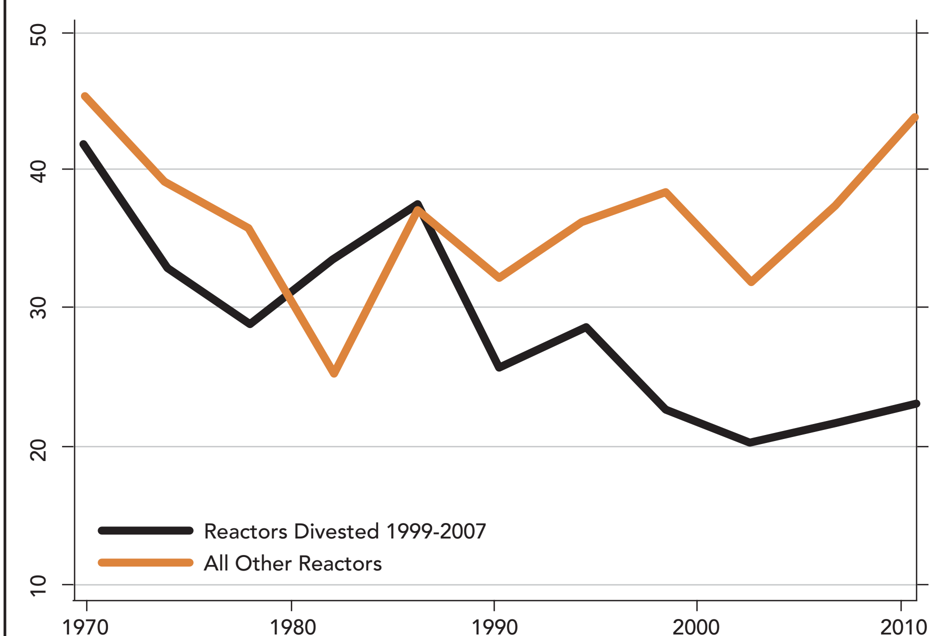


FIGURE 3: MEAN NUMBER OF OUTAGE DAYS PER YEAR, 1999-2009



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- *Control of Greenhouse Gas Emissions Resulting from Electricity Usage*
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